# TRANSLATION

ATTACHMENT FOR MEASURING
SMALL TIME INTERVALS

By

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## FOREIGN TECHNOLOGY DIVISION

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# UNEDITED ROUGH DRAFT TRANSLATION

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## Attachment for Measuring Small Time Intervals

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### Introduction

The mode of operation of the attachment is explained by the block-diagram in fig.1. The pulses corresponding to beginning and end of measured interval go to input forming blocks, and then - to the primary transformation scheme, where the measured interval is transformed into a pulse amplitude

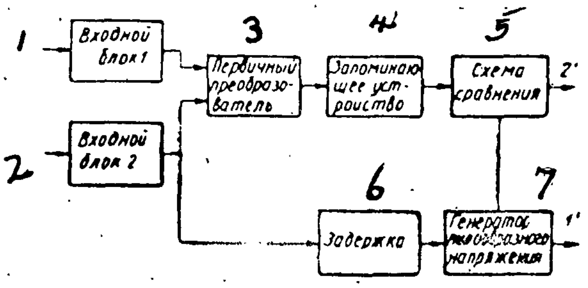

Fig.1.Block-diagram of attachment; 1-input block 1; 2-input block 2; 3-primary transformer; 4-memory device; 5-comparison circuit; 6-delay; 7-sawtooth voltage generator.

The obtained pulse after expansion goes to the comparison circuit, the output signal from which is delayed with respect to the straight movement of a saw for a time, proportional to the measured pulse amplitude, i.e. proportional to the measured time interval.

### Transformation of Measured Time Interval into Pulse Amplitude

The mode of operation of the converter which transforms the time interval into pulse amplitude [1, 2] is ordinary for the integrator (fig.2). In initial state both keys $K_1$ and $K_2$ are closed, and capacitor C is charged to the potential $U_0$. At the moment $t_0$, corresponding to the initial (beginning) of the measured interval is opened key $K_1$ and the capacitance C is being discharged by the current generator, i.e.

the potential on the plates drops linearly with time. At the moment $t_1$ (end of measured interval) key $K_2$ opens and the voltage on the capacitance remains unchanged (leakage is disregarded) In this way, $t_x$ is characterized by the change in voltage at the capacitance.

In the role of keys in a real circuit are used electronic tubes $L_1$ ($K_1$) and $L_2$ ($K_2$) (fig.3). Tube $L_1$- pentode with secondary emission of the 6V1P type. A characteristic feature of the tubes with secondary emission is, that the current flows from the dynode in the outer circuit, in given case through anode of pentode $L_2$. The function of the dynode in role of current generator is possible along a certain part of voltampere characteristic MP (fig.4).

Tube $L_2$, appears to be a current generator in the inte-ration curcuit, and is the circuit load of the dynode. Since the grid of the tubs is fed independently from the anode, and in the cathode exists resistance $R_k$, the anodic characteristic is shifted along the voltage axis by a value greater than UM. The displacement is necessary that the dynode current characteristics $L_1$ and plate current characteristics $L_2$ should intersect in one point only.

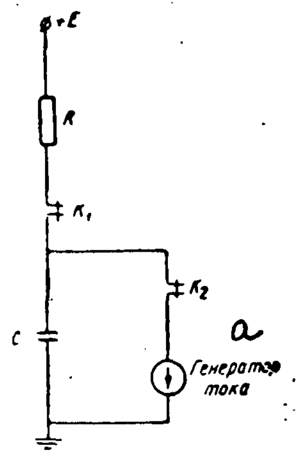


Fig.2.Schematic of primary conversion a–current generator.

Characteristics of dynode current $L_1$ and anodic characteristic of tube 6ZH4 ($L_2$) are shown in fig.5. Selection of this tube is explained by the fact that it has a greater internal resistance at greater working current (order of 10 ma).

The working current of the Dynode $L_1$ - anode $L_2$ circuit is derived from the intersection of their characteristics (point N in fig.5).

In the given system three points of stable equilibrium- point $N(i = i_o, U = U_o)$ point $O(i=0)$, $(U=0)$ and point $P(i = 0, U = U_3)$. Point M is unstable.

To bring the system beyond point $M$, i.e. into the working zone, where the dynode appears to be the current generator, it is necessary before operation to feed to the dynode a voltage, greater than $U_M$. This is realized with the aid of relay R (see fig. 3.) the contacts of which open up after the tubes become heated.

When at input I arrives a negative pulse with amplitude sufficient for closing $L_1$ on the control grid then $i = 0$ and the point of stable equilibrium is 0, i.e. the system tries to return into that point, which corresponds to the discharge of capacitor C through pentode $L_2$

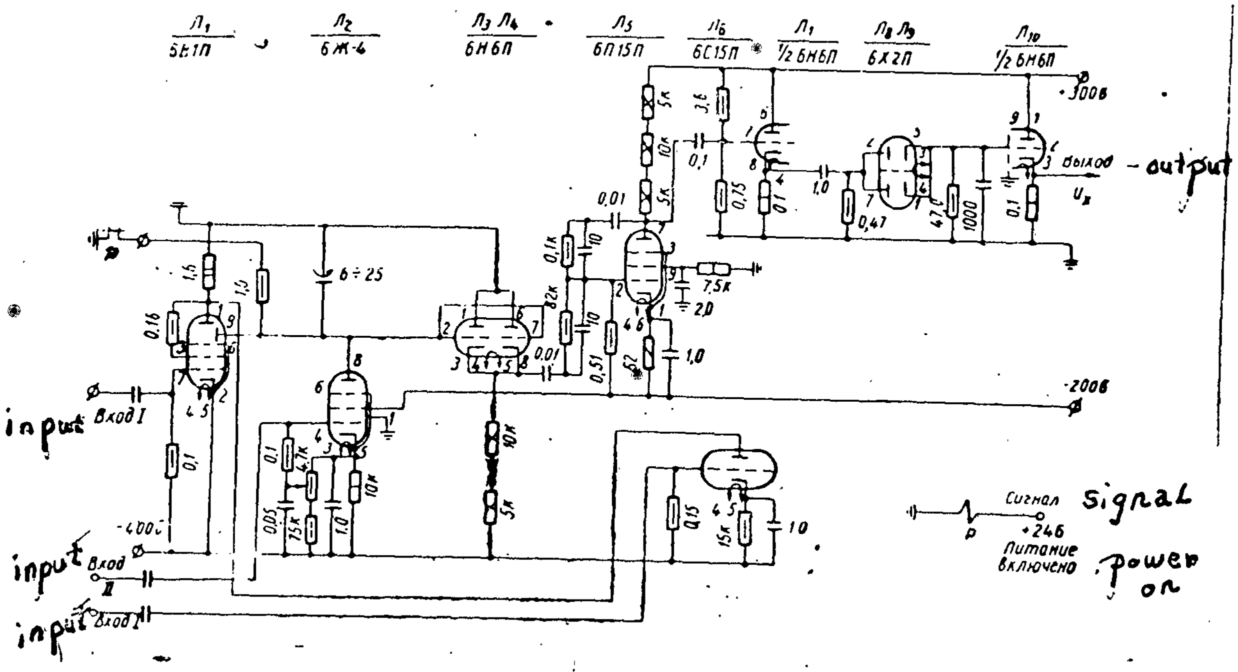


Fig.3. Principal circuit diagram of primary transformation

At the moment $t_1$ also $L_2$ closes ($L_1$ remains as before, closed). Voltage on the capacitor remains equal $U'_1$ (see fig. 4). Upon restoration of conductivity the system returns again into point N.

The return of the system into point N depends upon the ratio of durations of

first and second pulses.

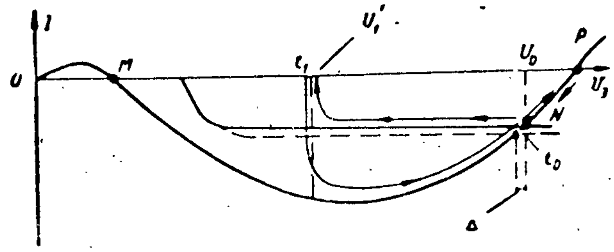

Fig.4. Schematic drawing of the operation of the system.

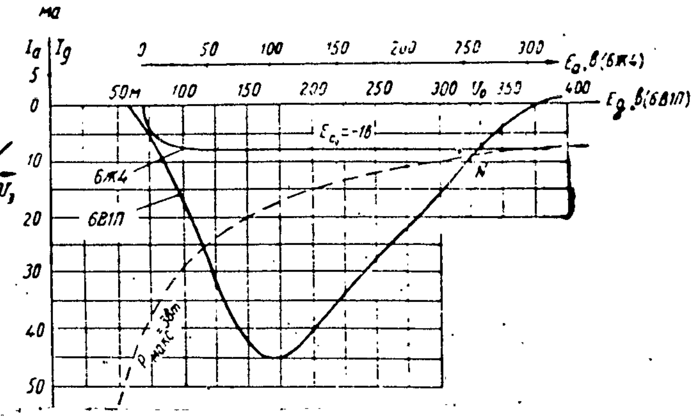


Fig.5. Dynode characteristic of 6V1P tube and plate characteristic of 6ZH4 tube [$I_g = f(E_g)$ at $E_a$ = 400 v; $E_{C_2}$ = 250 v; $E_{C_1}$ = - 2 v; $U_H$ = 6.3 v]

1. The duration of the first pulse is shorter than the duration of the second one. Time diagrams, explaining the form of the output voltage for this case, are shown in fig.6,a. As result of capacitor discharge in the cathode-pentode circuit at the time when $L_2$ is closed, its characteristic is shifted in direction of greater currents (dotted curve on fig.4), and this results in the appearance $\Delta$ (fig.6,a). Consequently at small $t_x$ $\Delta U_2$ may appear greater than $\Delta U_1$. The section $U_0$-$U_1'$ - working, i.e. $\Delta U_1$ characterizes $t_x$.

2. Duration of the first pules is greater than duration of the second one (fig.6,b). In this case the maximum amplitude characterizes not only $t_x$, but also the excess in duration of the first pulse over the duration of the second.

It is clear from this statement, that it is necessary to measure the amplitude of the pulse at the time when both tubes are off (closed)

A change in voltage on capacitor C:

$$\Delta U = \frac{i \cdot t_x}{C}, \quad a$$

where C - total capacitance (parasitic including); $t_x$ - measured time; i-discharge current of capacitor (current of pentode $L_2$).

The discharge current in first approximation can be considered as constant and

equal to $i_o$.

$$\text{Sensitivity of the system: } \frac{dU}{dt_x} = \frac{i}{C}$$

The sensitivity is limited by the magnitude $i_o$, because the capacitance cannot be lower than the parasitic. For 6V1P tube the current $i_o$ should be not more than 10 ma from the condition of permissible power scattered by the dynode.

In addition to sensitivity, is limited also the magnitude of maximum output voltage $\Delta U_1$ (it is included between $U_3$ and that voltage at which the plate current characteristic of the pentode still does not depend upon the plate voltage). The working zone is evident from fig.5. When using 6V1P and 6ZH4 $\Delta U_1 \approx 200$ v.

In this way, at maximum sensitivity the maximum time, the one which can be measured, equals:

$$t_{x\ max} = \frac{200.30.10^{-12}}{10.10^{-3}} = 6 \cdot 10^{-7} \text{ sec.}$$

( 0.6 microsec).

The smallest time interval, which can be measured, is determined by the system of measuring the pulse amplitude and by the magnitudes of transformation errors. If the absolute measuring error does not exceed 0.5 v, then the absolute error of measuring the time interval does not exceed $1.5 \cdot 10^{-9}$ sec (in the absence of other errors).

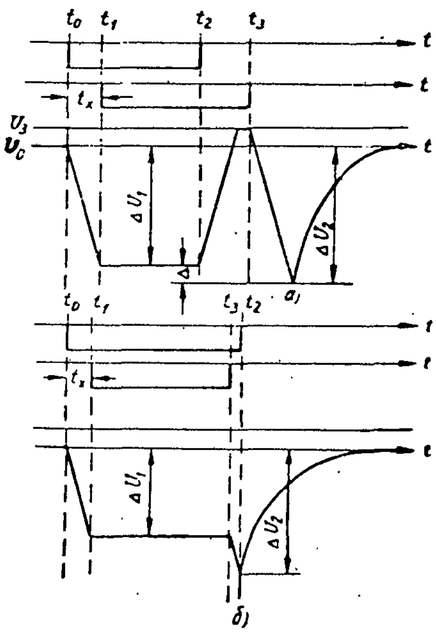


Fig.6. Form of output voltage in dependence on the ratio of durations of input pulses

Sources of Error

1. Nonuniform discharge current of capacitor. The discharge current during the use of 6ZH4 tube is constant with an accuracy of $\sim 5\%$. When i is replaced by DC current $i_o$ is obtained an error in determining the time:

$$\Delta t \approx 2.3 \cdot 10^{-9} \text{ sec.}$$

2. Instability of $i_o$ in time. Instability of pentode current of the order of 1% depends upon the time of tube operation, power stability, $R_k$ etc. Since $i_o$ changes are slow in time, they can be eliminated by periodic calibration.

3. Instability of capacitance C originates as result of temperature change, change of tubes etc, it is therefore desirable to have a concentrated capacitance of possibly greater value.

4. Non-instantaneous closing of keys $L_1$ and $L_2$. The diagram of an input monovibrator on tube with secondary emission is shown in fig.7,a. This circuit assures a pulse with amplitude ~ 70 v and forward front of 5 nsec (fig.7,b). The tube shuts off in time:

$$t_3 = t_{\phi} \cdot \frac{U_3}{U_{pul}}$$

When $t_p$ = 5 nsec, $U_3$ = 5 v and $U_{pul}$ = 50 v, $t_3 = 5 \cdot 10^{-10}$ sec.

Such an error can be disregarded.

5. Error due to capacitor leakage. The error due to capacitor leakage appears in form of change in voltage on the dynode, while both tubes are closed. Leakage is due not only to imperfect insulation of details. Somewhat unexpected appears to be the leakage along the dynode, in spite of the fact that 6V1P is deeply shut along the control grid. Through the dynode flow current of considerable magnitude within a certain time after feeding closing voltage to the grid.

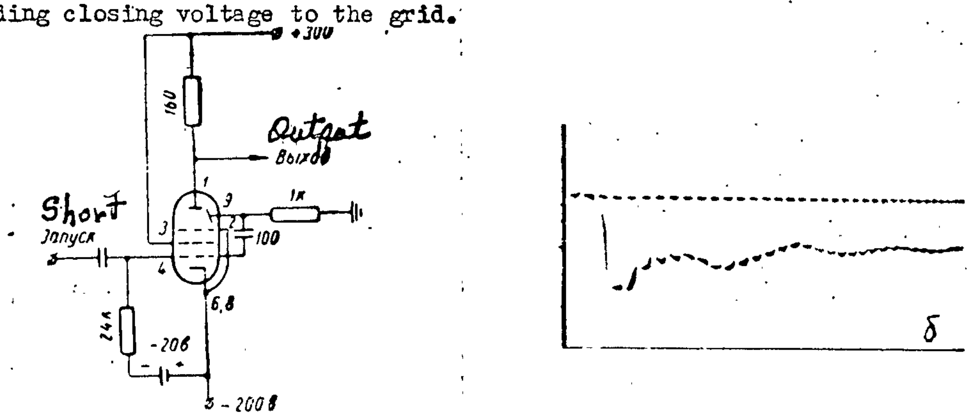


Fig.7. Diagram of input monovibrator (a) and forward front of output pulse (b). Time duration markers $10^{-8}$ sec.

The time constant, with which the dynode current tends toward zero, constitutes a mag.

nitude of the order of 2 sec. The initial dynode leakage current (immediately after tube shut off) has a value of 100-500 ma, although in some tubes it reaches up to 2 ma.

Leakage on account of the dynode leads to the point, after both tubes are closed, but the voltage on the integrating capacitor begins shifting toward the potential, determinable by the divider, in which are included the equivalent resistance of the dynode and insulation resistances. The mentioned phenomenon can produce a rise in potential on the capacitor as well as reduction of same.

The most radical method of combatting the error due to dynode conductivity is the selection of tube. Conductivity can be reduced by considerably reducing the plate voltage of tube 6V1P simultaneously with the arrival of the negative pulse on the controlling tube. For this purpose in the circuit is included a special tube $L_6$ (6S15P).

It is also desirable to measure the pulse amplitude possibly faster.

## Measuring Pulse Amplitude

Measuring the amplitude of a pulse, obtained as result of primary transformation, is realized with the aid of a comparison circuit.

Comparison circuits are quite well described in literature [3] and that is why no error analysis is given here. We want to mention, that the error of the comparison circuit can be brought up to 0.2 v, which gives an error of the magnitude of $10^{-9}$ sec for primary (measured) time interval. With the aid of comparison circuit the unknown voltage is transformed into a time interval, greater than $t_x$. Since the described circuit was developed for application to the industrial time measuring device type IV-13 the maximum $t_x$ value was selected at 100 msec.

To convert the pulse amplitude into such a greater secondary time interval it is necessary:

1) to have a duration of input signals greater than $t_x$, which is assured by input monovibrators;

2) "remember" for a time greater than $t_x$ the amplitude of the obtained pulse,

so that during secondary conversion the remembered voltage would not change noticeably.

To realize the memorizing the voltage pulse through cathode repeater $L_3$,$L_4$ goes to cascade with negative feedback $L_5$,serving for changing the polarity of the measured signal.

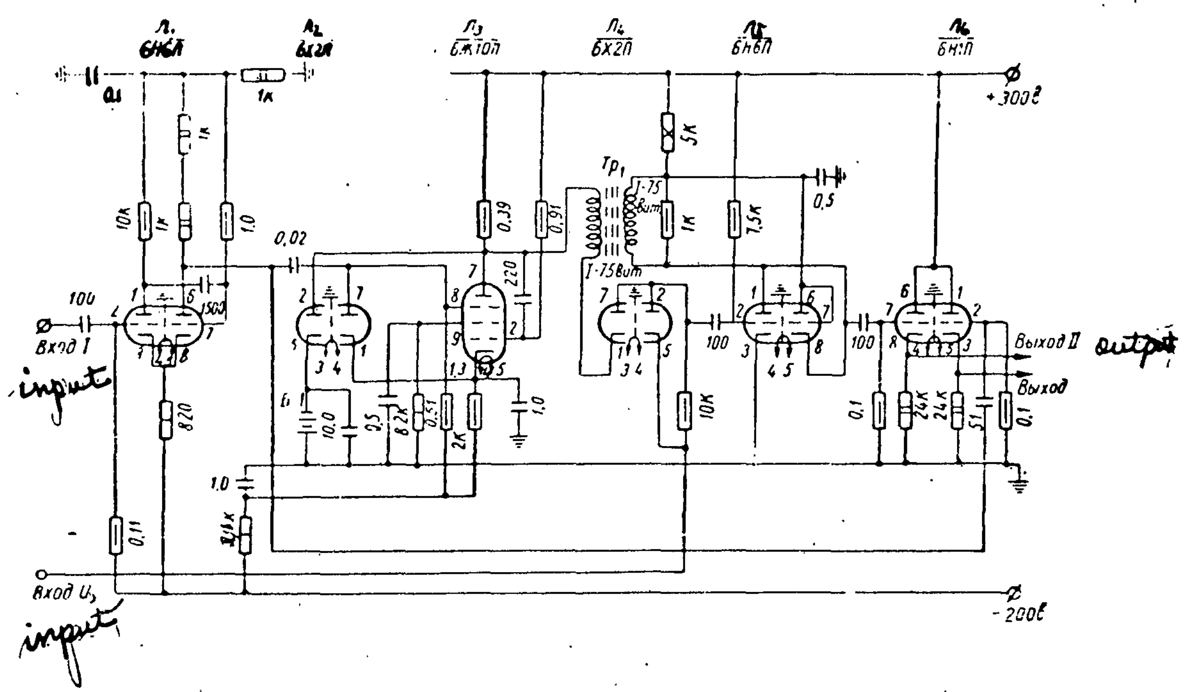


Fig.8.Principal circuit diagram of comparison block

Immediately after the cascade on $L_5$ memorizing cannot be made,because this cascade has a greater output resistance for the positive front of the signal (just as the cathode repeater - for the negative). Consequently the signal then goes to the cathode repeater ($L_7$),at the output of which aftare the diode $L_8$,$L_9$ stards the memory capacitor C = 1000 micromicrofareds. The time constant of the discharge of this capacitor is determined by the leakage of the output cathode repeater and equals $\sim$ 50 msec, i.e.at the time $t_x$ = 100 msec the voltage will change by not more than 0.2%, which is fully permissible.

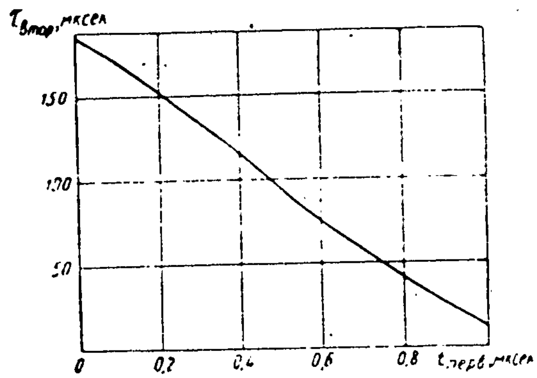


Fig.9. Graduation curve of attachment

The measured voltage from output cathode repeater (output $U_x$) goes to the input of the comparison circuit (fig.8).

At the moment of activating the generator of linearly falling voltage from output I comes out initial pulse $t_x$, and at the moment of comparison from output II - the end pulse $t_x$. Both these pulses go to the oscillographic time measuring device with spiral scanner.

In addition to the mentioned errors are added errors due to the memory circuit etc. The graduation curve of the attachment is shown in fig.9. Stability of any point is no-less than $10^{-9}$ sec. Total transformation accuracy $\sim$ 1% in spite of the fact that the sensitivity is much higher and constitutes a value of about $2 \cdot 10^{-9}$ sec.

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